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Do Living Mulches or Environmental Conditions Have a Greater Impact on the External Quality of the Apple Fruit 'Chopin' Cultivar?

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Abstract: Research was carried out to assess the yield and quality of fruits from the new Polish apple tree 'Chopin'—a 'green peel', scab-resistant cultivar under grass living mulch management. Blue fescue and red fescue were tested in experiment no. 1. In experiment no. 2, meadow grass and perennial ryegrass were used. Every species of grass was sown in two doses of 50 and 150 kg per ha. Herbicide fallow was introduced as a control in both experiments. Strongly variable temperatures and precipitations in the years of evaluation made it possible to estimate year—a function of variable environmental conditions—as an additional experimental factor. An unexpected effect of the presence of living mulch was its significant impact on the appearance of blush on the 'green peel' fruit. However, living mulches had little effect on weight and fruit size. Cool days during apple ripening enhanced the process of fruit skin red coloration. The effect of both agrotechnical and environmental factors on fruit quality was more visible in the case of less vigorous trees, which were more susceptible to experimental, stressful conditions. However, increasing the sowing dose of each grass seed did not influence red blushing, weight, or fruit size. An additional difficulty for the trees was the competition caused by the early germination of these living grass mulches, reinforced by the presence of *Trifolium repens* L.

Keywords: blushing; fruit size; cover crop; thermal conditions; water conditions

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1. Introduction

A modern view of agricultural production emphasizes the need for the sustainable use of agrochemicals due to the potential, undesirable impact of active substances on the safety of produced food [1,2] and the agricultural environment [3]. Therefore, the use of glyphosate-based herbicides in integrated agricultural systems should be eliminated [4,5]. Fruit production faces the challenges of providing a valuable, quality product for the consumer [6,7] and transforming the orchard into a place that serves as an element of a sustainable environment [8]. Chemical weed control can be replaced by alternative methods of weed control, for example, using living mulch [9–11]. In addition to weed control [11–14], living mulch offers other benefits for the orchard agroecosystem, including an increase in flora biodiversity [8] and organic matter in the soil [15–17], and it also affects the chemical [15,17,18] and biological [19,20] properties of soil. Species of the Poaceae family are often used as cover plants in perennial fruit crops [21]. Among grasses, species of the *Festuca* genus deserve special attention, especially blue fescue (*F. ovina* L.) [7,22] and red fescue (*F. rubra* L.) [23–26]. Other grasses used in fruit production include meadow grass (*Poa pratensis* L.) [23,26,27] and perennial ryegrass (*Lolium perenne* L.) [15,25,27].

The presence of living mulches causes discomfort for fruit trees, which may result in reduced tree yield [22,24,26,27]. With the appropriate choice of both cover crops and agrotechnical methods, the competition of living mulch relative to the cultivated plant can be mitigated [7,22,28]. However, there is an impact on fruit quality [7,22]. The external features of apples like size or the color of the skin are determined by both agrotechnical and environmental growing conditions [29] and are important for the individual choice of fruit of the consumer [30,31]. Cover crops in apple orchards significantly increased the area of 'red skin' [7,27], but the presence of additional vegetation, even weeds, did not determine the intensity of the basic color of the fruit in the case of 'yellow peel' apple [32]. On the other hand, mean apple fruit weight and size may be reduced compared to fruits from trees grown in herbicide fallow [22,25]. Environmental factors can also play an important role in fruit quality. External quality factors such as color, size, shape, and russeting are determined by the following factors: temperature, light, and precipitation, which vary in individual years and areas of fruit cultivation [29,33,34]. Warmer temperatures inhibit anthocyanin accumulation, which is responsible for the red blushing of apple skin [35], although they are necessary for the proper development of fruit in terms of size [36].

The aim of the study was to investigate the effect of living grass mulches on the external parameters of fruit from the new Polish apple tree 'Chopin'—a green peel, scab-resistant cultivar. Strongly variable temperatures and precipitations in the years of evaluation made it possible to estimate yearly conditions as an additional experimental factor and their impact on apple quality as a direct effect or result of the interaction with the presence of a cover crop.

2. Materials and Methods

2.1. Plant Material and Two Field Experiments

The influence of grass living mulches on the external parameters of fruit from the Polish apple tree 'Chopin'—a new, 'green peel', scab-resistant cultivar—was estimated. This study was conducted at the Fruit Experimental Station of the Wrocław University of Environmental and Life Sciences in Wrocław (Poland), Samotwór (51°06′12″ N, 16°49′52″ E) in the years of 2016−2021. Two-year-old apple trees (*Malus domestica* Borkh.) grafted on a semi-dwarf MM.106 rootstock were planted in the spring of 2016 on haplic luvisol. The chosen spacing was 3.6 m between tree rows and 1.2 m as a distance between trees in a row. In the spring of 2016, soil samples were taken from the entire area of the experimental field before planting the trees. Initial soil analysis showed an average level of available phosphorus and potassium and a high level of magnesium. The K:Mg ratio was proper (1.00). On this basis, the fertilizer doses of phosphorus (P_2O_5 100 kg per ha), potassium (K_2O 100 kg per ha), and liming (CaO 500 kg per ha) were determined.

Two separate experiments were established, each following a one-way randomized block design in four repetitions. Each repetition was represented by an experimental plot with four trees growing on it. In experiment no. 1, blue fescue (*Festuca ovina* L.) of the 'Noni' cv. and red fescue (*F. rubra* L.) of the 'Adio' cv. as living mulches were sown. The mean cross-sectional area of the tree trunk was 2.44 cm^2, in this experiment, when grass cover crops were sown in the early summer of 2017. The living mulches in experiment no. 2 were represented by meadow grass (Kentucky bluegrass) (*Poa pratensis* L.) of the 'Niweta' cv. and perennial ryegrass (*Lolium perenne* L.) of the 'Info' cv. The apple trees in this experiment were weaker than in experiment no. 1 and their mean trunk cross-sectional area was only 1.72 cm^2. Compared to trees in experiment no. 1, the growth of 'Chopin' cv. was lower than with all treatments in experiment no. 2. This could have been related to the presence of grubs causing damage to the root systems that, in some cases, even killed several trees in the year 2016–2017. This affected the growth and development of young trees in this year and most likely in the subsequent years. On the contrary, in experiment no. 1, the presence of grubs was sporadic and only caused the death of two trees.

Each estimated grass was sown separately at a dose of 50 kg and a dose of three times more—150 kg seeds per ha—in the 1.0 m wide tree rows as well as in the 2.6 m wide adjacent tractor alleys on the western side of each row. At the beginning of June 2017, the grass seeds were scattered by hand and raked into the soil in the tree rows, after which the floor was rolled with a hand roll. Like in the tree rows, the grass seeds in the alleys were scattered by hand, but the following cultivation was limited to rolling with a roll pulled by a tractor. The grass sod in the tree rows was mowed manually, twice or three times per year, with a string trimmer every year. But, the grass sod in the tractor alleys was mowed with a lawn mower several times per year. In both cases, the mowed biomass of grass was left.

A control treatment using herbicide fallow was created separately for each experiment. It was treated with a mix of glyphosate (1.44–1.96 kg ha^{-1}) and MCPA (2-methyl-4-chlorophenoxyacetic acid, 0.60–1.00 kg ha^{-1}) two or three times a year: in spring (April or May), summer (July), and, in some years, at the end of the vegetation period. A grass mixture was sown in the alleys adjacent to the herbicide fallow plots. The trees were trained into a slender spindle canopy form. After the second year of orchard establishment, each tree was fertilized with ammonium nitrate (15 g N in the years 2017−2018 and 20 g N in the years 2019−2021) separately. The cutting of the trees as well as plant protection were managed in accordance with current commercial orchard recommendations. Manual hand thinning of fruit sets was performed only at the beginning of June in the year 2020.

2.2. Living Mulch Sod and Weediness Estimation

The separate plot area for each individually estimated grass was 17.28 m^2 (3.6 m × 4.8 m) and contained four apple trees. In the middle part of the plot area, two sub-plots were designated—the first for the assessment of living mulch sod and weed infestation in the tree row (1.80 m^2) and the second for only sod estimation in the tractor alley (4.68 m^2). Whole-plot evaluation was abandoned to avoid the non-representative weed communities that occurred at the edges of the investigated living grass mulches. The degree of soil coverage by living mulches was assessed as the percentage of the total area of sub-plots occupied by the cover crop sod. Using the same plots, but only in the tree rows, the percentage of the soil surface occupied by weed taxa was determined. For this purpose, a noninvasive method of weed population assessment, conforming to the modified methodology of Lipecki and Janisz [37], was employed. The original share of the scale was modified by splitting the range over 0% up to 20% into two separate groups and, as a final result, each taxon was expressed using a discrete percentage scale: 0%, 1%, 20%, 40%, 60%, 80%, and 100%. The assessments were performed separately for each species and, in some cases, genus, of the weed. As the share of each species was assessed independently, it was impossible to express the relationship between the total share of all weed populations and the sod of the living mulch at a scale of 100%. The living mulch sod cover estimation was performed in the autumn of every year (2017–2021). The weed taxa assessment took place in the last year of the research, in the spring of 2021. The nomenclature of vascular plants was based on POWO [38].

2.3. Soil Analysis

In the spring of 2022, 'A horozon' topsoil samples were collected from the tree rows in each sub-plot in experiment no. 2. Soil analyses were performed at the Chemical and Agricultural Station in Wrocław (Poland). The available elements (K, Mg, Ca) were determined using the Mehlich-3 method [39,40]. Phosphorus was determined colorimetrically using the vanadium method [41]. In addition, pH was determined in 1 mol KCl L^{-1} by the potentiometric method [41] and soil organic carbon (SOC) was determined by the Tiurin method. The assessment of soil nutrient content was carried out in relation to the limit numbers developed by Sadowski et al. [42].

2.4. Yield, Fruit Quality, and the Growth of Apple Trees

In both experiments, each tree was individually assessed for the abundance of flowering, number of fruits, and yield in the years 2017–2021. Flowering was assessed on each tree according to a scale of 0–5, where 0 meant no flowers and 5 meant a very abundant cover of the tree with flowers. During harvest, the number of fruits on each tree was counted and its yield was weighed. The fruit was harvested in the last days of September or the first days of October. Fruit quality assessments were carried out in 2018–2021; the year 2017 was omitted due to hail damage to the apples. The fruit weight was calculated as a ratio of yield mass to the number of fruits and was computed separately for each tree every year. All harvested apples per repetition were sorted into classes—over 75%, 25–75%, or less than 25% of fruit skin red blush surface. It should be noted that the color and intensity of the blush appearing on the 'green-peel' 'Chopin' cv. did not reach the typical red color but rather oscillated towards light red-pink blushing (Scheme S1). Apples were also divided into classes of fruit diameter: less than 6.5, 6.5−7.5, 7.5−8.5, and over 8.5 cm. As a measure of each tree's growth, trunk cross-sectional area (TCSA) and its increment were calculated as an average of the diameter measured in two directions (north–south and east–west directions), measured 30 cm above the grafting point. The measurements were made in autumn 2016 and autumn 2021. The crop efficiency coefficient (CEC) was computed as a ratio of the total yield of five years (2017−2021) and TCSA in the autumn of 2021.

2.5. Statistical Evaluation

All annual and mean data connected with the growth and yield of the trees were evaluated statistically using one-way analysis of variance (ANOVA) for a randomized block design in RStudio software (version 2023.12.1). Prior to the analysis, in order to—at least approximately—fulfill the assumptions of the analysis of variance, angular (by the function of Bliss), logarithmic, or exponential transformations were applied to some of the data. Due to the death of some trees, the measurement system (data presented: yield, growth, and fruit quality) was balanced using the missing plot technique procedure. Significant differences between treatment means were calculated with the Tukey test ($p \leq 0.05$). Means were presented with standard deviations (mean ± SD).

In addition, a two-way analysis of variance (ANOVA) was also performed when data from individual years was taken into account as a second research factor to identify the effects of yearly conditions (YEAR), living grass mulch species with either their seed sowing dose or herbicide fallow (GLMHL), and the interaction of these two factors (YEAR × GLMHL) on the variables connected with fruit quality parameters only. Significant differences in interactions were noted at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$. This statistical analysis of data was supplemented with a linear correlation analysis ($p = 0.05$), in which the selected thermal condition and precipitation impacts on the quality of individual fruits were assessed.

3. Results and Discussion

3.1. Annual Temperature and Total Precipitation with a Focus on the Fruit Ripening Period

The year of tree planting (2016) and the year of sowing living mulches (2017) were characterized by moderate mean monthly and annual air temperatures (Tables 1 and S1). The distribution of monthly total precipitation was even, except for the peak in both years in July. In the next two years (2018–2019), very high mean monthly summer temperatures were recorded, and the annual rainfall showed a deficit (less than 450 mm) compared to the first two years of the experiment. On the contrary, in the next study year (2020), rainfall from May to October was very high, especially in the relatively cold month of June. In the last year of research, the mean annual air temperature was low, despite the records for June and July when mean monthly air temperatures exceeded 20 °C. Precipitation was less than in the first year of research.

In the first five years of cropping, which is associated with the end of September and the beginning of October in Poland, the fruits ripened in very diverse weather conditions (Tables 1 and S1). In the summer of 2017, hail damaged the skin of the apples, which disrupted their growth. In subsequent years of research, September 2018 was exceptionally warm (Figure S1). The apple harvest was carried out on 2 October. In the 30 days preceding harvest, the maximum air temperature reached above 25.0 °C for as many as 10 days. In this year (2018), the number of days with a minimum temperature below 5.0 °C reached 5 days. This was 2 days higher compared to the remaining years of the study. Noticeable cooling was noted mainly before fruit harvest (Figure S1). It can be assumed that such thermal conditions in 2018 were conducive to fruit skin red coloring. Anthocyanin synthesis, responsible for the red blushing of apple skins, increases with decreasing temperatures during fruit ripening [33,35].

Table 1. Mean annual temperatures and total precipitation at the Wrocław-Strachowice Station (51°12′ N, 16°87′ E) and characteristics of thermal conditions and rainfall during fruit ripening a month before fruit harvest in the years 2017–2021.

Specification	Year				
	2017 *	**2018**	**2019**	**2020**	**2021**
Mean annual temperature (°C)	9.8	10.8	11.0	10.6	9.4
No. of days during fruit ripening with minimum temperature:					
0.0–5.0 °C	3	5	3	3	3
5.1–10.0 °C	17	9	11	13	12
10.1–15.0 °C	10	15	15	14	14
15.1–20.0 °C	–	1	1	–	1
No. of days during fruit ripening with maximum temperature:					
10.1–15.0 °C	4	4	5	5	4
15.1–20.0 °C	24	8	14	9	8
20.1–25.0 °C	2	8	10	8	14
25.1–35.0 °C	–	10	1	8	4
Total precipitation (mm):					
January–December	619.3	441.4	430.8	808.4	540.3
January–September	478.6	343.1	348.3	667.5	457.2
September	65.1	45.9	53.0	94.2	24.2
No. of days in September with precipitation => 0.1 mm	15	8	15	9	11

*—hail shower.

In the following years (2019–2021), the distribution of the number of days with individual ranges for minimum temperatures was similar. It is worth noting that in 2019, as many as 10 days with a minimum temperature below 10 °C were recorded in the second half of September (Figure S1), just before the fruit harvest, which was on the last day of the month. In 2020 and 2021, the number of such days in the second half of September was lower. At the same time, they were accompanied by relatively high maximum temperatures, which additionally did not favor the red coloring of the apple skins compared to more favorable thermal conditions in 2018 and 2019.

In 2018–2019, from January to the end of September, the total rainfall was very low (Tables 1 and S1). Trees with ripening fruits had better conditions in 2017 and 2021, and the best conditions were in 2020, which was exceptionally abundant in precipitation. This was the only year in the study in which the amount of rainfall could be classified as ensuring 'good fruit quality' in apple production [29]. The highest rainfall in September was also recorded in 2020; it was twice as low in 2018 and four times lower in the last year of tree fruiting (2021). The number of days with precipitation ranged in September from 8—in the exceptionally warm fruit ripening period in 2018—to 1 day more, which was recorded in the exceptionally rainy year of 2020, and, in other years, it even reached 15 days.

3.2. Characteristics of Living Mulch Sod and Weed Infestation

The choice of the beginning of June 2017 as the seed sowing date for the tested grasses turned out to be beneficial because, during establishment and in summer, further development of the living mulch sod was accompanied by adequate moisture (Table S1). Proper growth conditions were provided that stimulated seed germination and the abundant development of cover crop biomass [43,44]. In both experiments, however, the percentage of the soil surface covered with four living grass mulches varied greatly in the year of sowing (Table 2). In experiment no. 1, the development of blue fescue sod was very slow and the soil cover in the autumn of 2017 was unsatisfactory compared to that of red fescue. This could have been due to the differential ability of fescue cultivars to rapidly establish [45]. In experiment no. 2, perennial ryegrass, regardless of the seed sowing dose used, filled 100% of the orchard area in the year of sowing. Meadow grass gained by such a year later.

Table 2. Percentage of the soil surface under the covering of different living grass mulch sods in the tree rows and alleyways in the succeeding years 2017−2021.

Year	Living Grass Mulch Species and Seed Sowing Dose (kg·ha^{-1})							
	Experiment 1				Experiment 2			
	Blue Fescue		Red Fescue		Meadow Grass		Perennial Ryegrass	
	50	150	50	150	50	150	50	150
Tree rows								
2017	10	5	65	85	60	80	100	100
2018	70	85	90	95	95	100	95	100
2019	95	100	100	100	100	100	100	100
2020	95	100	100	100	100	100	95	100
2021	100	85	100	100	100	100	100	100
Alleyways								
2017	20	50	90	95	80	85	100	100
2018	60	85	95	95	100	100	90	100
2019	80	100	95	100	100	100	100	100
2020	75	85	100	100	100	100	100	100
2021	70	75	75	85	100	100	95	100

For the perennial ryegrass, the very early germination of this species contributed to good sodding. It had already appeared between 10 and 20 days from the date of sowing the seeds compared to meadow grass and red or blue fescue, which germinated after 20 days at the earliest [46]. The soil cover of perennial ryegrass and meadow grass in 2018–2021 was stable and satisfactory. Despite this, weeds were spreading in the grass sod (Table 3).

Table 3. Diversity of the structure of identified weed taxa number and soil covering within four different living grass mulch sods in the tree rows in spring 2021.

Specification		Living Grass Mulch Species and Seed Sowing Dose (kg·ha^{-1})							
		Experiment No. 1				Experiment No. 2			
		Blue Fescue		Red Fescue		Meadow Grass		Perennial Ryegrass	
		50	150	50	150	50	150	50	150
Percentage of soil surface under individual weed taxa covering within sod:									
Achillea millefolium L.	ACHMI	0	5.0	0	0	0	5.0	0	0
Arabidopsis thaliana (L.) Heynh.	ARBTH	0	0	0	0	<1.0	<1.0	5.0	0
Artemisia vulgaris L.	ARTVU	0	0	5.0	0	<1.0	<1.0	0	<1.0
Calamagrostis epigejos (L.) Roth	CLMEP	5.0	0	0	0	0	0	0	0
Capsella bursa-pastoris (L.) Medik.	CAPBP	0	0	0	0	0	0	5.3	<1.0
Cerastium holosteoides Fr.	CERVU	5.0	0	0	0	15.3	10.3	20.0	5.5
Crepis spp.	CVPG	<1.0	0	0	0	0	0	0	<1.0
Draba verna L.	ERPVE	5.0	0	0	0	5.3	10.0	15.0	10.0
Elymus repens (L.) Gould	AGRRE	<1.0	0	0	0	15.0	<1.0	0	0
Hieracium spp.	HIEG	0	5.0	0	<1.0	5.0	<1.0	<1.0	0
Hypericum perforatum L.	HYPPE	<1.0	0	<1.0	0	0	<1.0	<1.0	0
Lamium purpureum L.	LAMPU	<1.0	0	0	0	5.8	5.5	15.3	10.3
Leontodon hispidus L.	LEBHI	<1.0	0	0	0	0	<1.0	<1.0	0
Malva sylvestris L.	MALSI	<1.0	0	0	0	0	<1.0	0	<1.0
Plantago major L.	PLAMA	0	0	0	<1.0	0	<1.0	0	0
Plantago lanceolata L.	PLALA	10.0	<1.0	0	0	0	0	<1.0	5.0
Poa annua L.	POAAN	0	0	0	0	0	0	0	<1.0
Poaceae—other species	GRAF	25.0	15.3	0	<1.0	15.3	5.5	10.0	<1.0
Ranunculus repens L.	RANRE	0	5.0	0	0	0	0	0	0

Table 3. *Cont.*

Specification		Living Grass Mulch Species and Seed Sowing Dose (kg·ha^{-1})							
		Experiment No. 1				Experiment No. 2			
		Blue Fescue		Red Fescue		Meadow Grass		Perennial Ryegrass	
		50	150	50	150	50	150	50	150
Rumex acetosa L.	RUMAC	<1.0	0	0	0	0	0	0	0
Stellaria media (L.) Vill.	STEME	<1.0	0	0	0	5.5	5.5	15.3	20.0
Taraxacum sp.	TARG	10.5	5.8	<1.0	<1.0	20.0	15.3	20.3	20.0
Trifolium repens L.	TRFRE	10.5	10.3	25.0	10.5	65.0	75.0	75.0	55.0
Veronica arvensis L.	VERAR	0	0	0	0	0	0	0	<1.0
Veronica serpyllifolia L.	VERSE	0	0	0	0	5.3	<1.0	0	0
Veronica sp.	VERG	0	0	0	0	<1.0	0	<1.0	<1.0
No. of weed taxa covering soil surface within sod:									
<1.0%		8	1	2	4	3	9	5	8
1.1–5.0%		3	3	1	–	1	1	1	1
5.1–10.0%		1	1	–	–	4	4	2	2
10.1–20.0%		2	2	–	1	4	2	4	3
20.1–40.0%		1	–	1	–	–	–	1	–
40.1–100.0%		–	–	–	–	1	1	1	1
Total number of weed taxa		15	7	4	5	13	17	14	15

In the spring of 2021, a large share of covering by *Trifolium repens* L. and *Taraxacum* sp. was already observed in the tree rows. These were two perennial weeds that were exceptionally bothering for orchard production using living mulch [16,25]. The use of different seed sowing doses did not have a significant impact on the coverage of these weed species. The share of typical monocotyledonous weeds in cover crops, such as *Elymus repens* (L.) Gould [27,47] or other species from the Poaceae family [16,47], was noted clearly in the present study when living meadow grass mulch was sown at the basic standard of only 50 kg of seeds per ha. In both grasses tested in experiment no. 2, the number of identified weed taxa increased from 13 to 17 and was similar to the blue fescue sod, which was sown at the standard dose of 50 kg of seeds per ha. The coverage of several of these weed taxa did not exceed 1% of the soil surface. They can therefore be considered as species contributing to the biodiversity of the agricultural landscape [48].

3.3. Soil Properties under Living Mulch Cover

The presence of living grass mulches and their weediness compared to the herbicide fallow did not result in significant differences in soil conditions in the first five years of apple tree cultivation (Table 4).

The soil reaction in all treatments was similar, and the organic C content did not exceed 11.0 g per kg. A similar content of organic C was determined by Ramos et al. [49] under native grass cover. In this experiment, only the frequent tillage of soil contributed to a significant decline in organic matter after several months. A significant effect of various living mulches, including perennial ryegrass, on the increase of organic C compared to mechanical soil cultivation was also shown after three years of research by Qian et al. [15]. In our five-year study, the control treatment, herbicide fallow, did not have such a strong effect on reducing soil organic C. But, the twelve-year impact of two living grass mulches in comparison with herbicide fallow and black woven polypropylene fabric improved the humus content of the soil [16]. Also, the three-year cultivation of various grass mixtures with dicotyledons or only dicotyledons contributed to an increase in the organic matter content of the soil [17].

Table 4. Selected chemical and physical–chemical properties of soil under living meadow grass or perennial ryegrass mulch sods and herbicide fallow in the tree rows—experiment no. 2, spring 2022 (mean ± SD, n = 4).

Specification	Herbicide Fallow	Living Grass Mulch Species and Seed Sowing Dose ($kg \cdot ha^{-1}$)			
		Meadow Grass		Perennial Ryegrass	
		50	150	50	150
pH_{KCl}	5.5 ± 0.8 a	5.6 ± 0.2 a	5.4 ± 0.5 a	5.4 ± 0.6 a	5.6 ± 0.9 a
$C_{org.}$ ($g \cdot kg^{-1}$)	10.8 ± 0.9 a	10.6 ± 1.1 a	10.5 ± 1.0 a	11.0 ± 1.2 a	10.6 ± 1.5 a
P ($mg \cdot kg^{-1}$)	36 ± 17 a	39 ± 9 a	42 ± 14 a	42 ± 13 a	42 ± 18 a
K ($mg \cdot kg^{-1}$)	103 ± 46 a	113 ± 22 a	105 ± 36 a	130 ± 68 a	127 ± 41 a
Mg ($mg \cdot kg^{-1}$)	88 ± 16 a	85 ± 11 a	80 ± 8 a	86 ± 15 a	87 ± 13 a
K:Mg	1.13 ± 0.32 a	1.31 ± 0.16 a	1.31 ± 0.36 a	1.45 ± 0.54 a	1.43 ± 0.25 a

Means marked with different letters in rows represent statistical differences among treatments (one-way ANOVA, Tukey test, $p \leq 0.05$).

The content of available phosphorus in the soil remained at an average level with herbicide fallow treatment. It was high in meadow grass sown at a dose of 150 kg per ha and in both treatments with perennial ryegrass. Regardless of the treatment, potassium and magnesium remained at medium and high levels, respectively, and the K:Mg ratio was always proper. A significant increase in soil phosphorus and potassium content was noted by Qian et al. [15] after three years of research in which mechanical cultivation was replaced by the use of several cover crops. Among them, living perennial ryegrass mulch provided significantly higher potassium contents. In other studies, compared to long-term herbicide fallow treatment, the presence of grass cover crops had a positive impact on the total soil nutrient contents [16].

3.4. Growth and Yield of Apple Trees

In the autumn of 2016, before the sowing of living mulches, stronger growth of the 'Chopin' apple tree on the strong semi-dwarf rootstock MM.106 was recorded in experiment no. 1 compared to experiment no. 2 (Tables 5 and 6).

Table 5. Yield and tree growth of 'Chopin' cv. depending on living blue fescue or red fescue mulch sods and herbicide fallow—experiment no. 1 (mean ± SD, n = 4).

Specification	Herbicide Fallow	Living Grass Mulch Species and Seed Sowing Dose ($kg \cdot ha^{-1}$)			
		Blue Fescue		Red Fescue	
		50	150	50	150
TCSA autumn 2016 (cm^2)	2.46 ± 0.88 a	2.69 ± 0.72 a	2.69 ± 0.41 a	2.16 ± 0.48 a	2.20 ± 0.56 a
TCSA increment spring 2016–autumn 2021 (cm^2)	24.62 ± 9.22 a	21.93 ± 4.25 a	23.96 ± 5.46 a	20.64 ± 5.71 a	18.51 ± 8.87 a
TCSA autumn 2021 (cm^2)	27.08 ± 10.09 a	24.63 ± 4.97 a	26.65 ± 5.86 a	22.80 ± 6.17 a	20.70 ± 9.40 a
Mean fruit number 2017–2021 ($no \cdot tree^{-1}$)	49 ± 8 b	30 ± 10 a	27 ± 5 a	24 ± 3 a	22 ± 3 a
Total yield 2017–2021 ($kg \cdot tree^{-1}$)	26.74 ± 3.30 b	18.82 ± 6.24 ab	16.66 ± 3.31 a	14.27 ± 0.90 a	12.34 ± 3.71 a
Crop efficiency coefficient 2017–2021 ($kg \cdot cm^{-2}$)	1.13 ± 0.55 a	0.76 ± 0.17 a	0.65 ± 0.20 a	0.67 ± 0.24 a	0.64 ± 0.14 a

TCSA—trunk cross-sectional area. Means marked with different letters in rows represent statistical differences among treatments (one-way ANOVA, Tukey test, $p \leq 0.05$).

Table 6. Yield and tree growth of 'Chopin' cv. with living meadow grass or perennial ryegrass mulch sods or herbicide fallow—experiment no. 2 (mean ± SD, n = 4).

Specification	Herbicide Fallow	Living Grass Mulch Species and Seed Sowing Dose ($kg \cdot ha^{-1}$)			
		Meadow Grass		Perennial Ryegrass	
		50	150	50	150
TCSA autumn 2016 (cm^2)	1.79 ± 0.11 a	1.58 ± 0.21 a	1.82 ± 0.14 a	1.70 ± 0.32 a	1.73 ± 0.20 a
TCSA increment spring 2016–autumn 2021 (cm^2)	16.64 ± 1.73 b	10.16 ± 1.61 a	11.64 ± 3.28 ab	10.44 ± 2.72 a	8.22 ± 0.80 a
TCSA autumn 2021 (cm^2)	18.42 ± 1.69 b	11.74 ± 1.80 a	13.46 ± 3.23 ab	12.13 ± 3.01 a	9.95 ± 0.98 a
Mean fruit number 2017–2021 ($no \cdot tree^{-1}$)	47 ± 14 b	23 ± 3 a	26 ± 3 a	16 ± 6 a	19 ± 2 a
Total yield 2017–2021 ($kg \cdot tree^{-1}$)	25.87 ± 5.72 b	11.99 ± 2.96 a	13.29 ± 1.47 a	8.50 ± 4.07 a	9.48 ± 2.05 a
Crop efficiency coefficient 2017–2021 ($kg \cdot cm^{-2}$)	1.39 ± 0.19 b	1.03 ± 0.25 ab	1.04 ± 0.31 ab	0.68 ± 0.22 a	0.96 ± 0.24 ab

TCSA—trunk cross-sectional area. Means marked with different letters in rows represent statistical differences among treatments (one-way ANOVA, Tukey test, $p \leq 0.05$).

These differences determined the growth of trees in subsequent years of research. Five years later, regardless of the sowing dose for the living grass mulches, all trees grown in fescue treatments had similar growth and trunk cross-sectional areas. Trees in herbicide fallow did not grow significantly stronger. This was similar in the experiment with good-quality nursery material, i.e., apple trees of the 'Ligol' cv. on semi-dwarf rootstocks with living blue fescue mulch [22]. Smaller trees whose trunk diameter did not exceed 2 cm^2 at the time of sowing living mulches in experiment no. 2 reacted more strongly to their presence (Table 6). Their increment and trunk cross-sectional area were often significantly lower compared to those noticed in cases of trees cultivated with herbicide fallow. Such a negative impact of living grass mulches was observed in other studies, not only in young apple orchards on dwarf rootstocks [22,26] but also when trees were grafted on the strongly growing MM.111 rootstock with the use of the M.9 interstock [24]. With the same soil nutrient content in all treatments in experiment no. 2 (Table 3), it can be assumed that the rapid development of living mulch sod in the orchard contributed to the limitation of tree growth. This was also due to the more abundant weed cover for meadow grass and perennial ryegrass than in experiment no. 1 for both fescue sods (Tables 2 and 3). Unfortunately, a negative impact of the presence of soil grubs on the condition and growth of the tree root system in experiment no. 2 cannot be excluded. This could have weakened the growth of young trees in the first years after establishing the orchard and additionally strengthened the negative impact of living mulch on the level of tree yield (Table 6).

The influence of both fescue species in experiment no. 1 sown at a dose of 150 kg per ha and of red fescue sown at a dose of 50 kg per ha were also factors that significantly decreased the number of fruits and yield of trees cultivated with living mulches compared to herbicide fallow (Table 5). This reaction of trees to the presence of a cover crop was expected because other previous studies showed the influence of the competition of an additional plant in the orchard on the level of apple tree fruiting [22,26]. However, the very low yield of all trees in both experiments is worthy of attention. It increased in subsequent years of the study, but even the most cropping trees in both control treatments with herbicide fallow gained only over 10 kg per tree in the fifth year (Tables S2 and S3). Such a low yield could have been the result of an inappropriately selected MM.106 rootstock for the new scab-resistant variety 'Chopin'. Although it is a semi-dwarf rootstock, it grows relatively strongly [50,51], which unfortunately delays trees' entry into full fruiting [50]. In the present study, this was also confirmed by the assessment of tree blooming, which most often remained below a value of 2, which indicated blooming below the average level (Figures S2 and S3). In the present research, the low yield per tree cultivated with fescue resulted in the crop efficiency coefficient being below unity, as in another experiment with red fescue [24]. This was similar in both treatments with perennial ryegrass.

3.5. Blushing, Mean Weight, and Size of Fruit

An unexpected effect of using living mulch in the orchard that was significant in experiment no. 2 was an increase in the share of apples with a red-pink color exceeding 25% of the skin surface compared to the herbicide fallow control (Table 7). However, the share of 'green peel' 'Chopin' cv. with blushing greater than 75% was occasional. The influence of cover plants on the increase in the red blush color area has been shown in various research experiments, but it has been connected with 'red skin' apples [7,22]. However, Atay et al. [32] did not observe differences in the basic yellow color of the fruit 'yellow skin' 'Golden Delicious' cv. when assessing the different intensities of weed infestation in the orchard. The competition of weeds against the tree can, to some extent, be compared to the competition created by our cover plants. Additionally, in the experiment of Atay et al. [32], the intensity of only the deep yellow color changed under the influence of yearly weather conditions. In the case of our research, different thermal conditions in September, in the period preceding fruit harvest, contributed to a significant increase in the share of red blush apples of the 'green-peel' variety (Tables 1 and S1). This was observed in both research experiments, but the interaction effect (living mulch × year) was significant only in the meadow grass and perennial ryegrass experiments.

Sawicka et al. [52] reported that the mean fruit weight of 'Chopin' cv. was 183 g. In our experiment, the fruit was smaller in all years of the study (Table 7). In 2019–2020, in experiment no. 1, the mean fruit weight was significantly lighter compared to 2018. Similar trends were noted in experiment no. 2. In both experiments, in the first two years of evaluation, a high share of apples with a diameter of 6.5–7.5 cm was recorded. In the next two years, the share of larger apples (7.5–8.5 cm) increased, even though the yield per tree most often increased compared to 2018–2019 (Tables S1 and S2). This could have been due to a much better supply of water to trees in 2020 and 2021 compared to 2018–2019 (Tables 1 and S1). The use of living mulch had no effect on fruit weight and diameter in experiment no. 1, similar to the findings of Bałuszyńska et al. [7]. However, other authors mentioned the negative impact of cover crops on fruit weight and size [22,25]. This tendency was present in experiment no. 2. Significant differences were noted when the herbicide fallow was replaced with meadow grass sown at a rate of 50 kg of seeds per ha.

Table 7. Mean fruit weight, blushing, and fruit size of 'Chopin' cv. with living grass mulch sods or herbicide fallow by year (mean ± SD, n = 4).

Specification	Mean Fruit Weight (g)	% of Fruit with Blush on Skin Surface Area			% of Fruit with Diameter (cm)			
		>75%	25–75%	<25%	>8.5	7.5–8.5	6.5–7.5	<6.5
Experiment No. 1								
GLMHL:								
Herbicide fallow	121 ± 9 a	–	12 ± 4 a	88 ± 4 a	1 ± 1	17 ± 5 a	57 ± 5 a	26 ± 10 a
Blue fescue 50	134 ± 8 a	–	20 ± 8 a	80 ± 8 a	2 ± 3	19 ± 8 a	57 ± 8 a	21 ± 8 a
Blue fescue 150	133 ± 6 a	–	20 ± 4 a	80 ± 4 a	1 ± 1	21 ± 4 a	59 ± 6 a	19 ± 6 a
Red fescue 50	138 ± 5 a	–	26 ± 1 a	74 ± 1 a	2 ± 2	23 ± 5 a	53 ± 4 a	22 ± 7 a
Red fescue 150	135 ± 13 a	–	22 ± 13 a	78 ± 14 a	3 ± 2	24 ± 7 a	53 ± 6 a	21 ± 12 a
YEAR:								
2018	142 ± 10 c	–	42 ± 2 c	58 ± 2 a	–	14 ± 9 a	71 ± 2 b	15 ± 9 a
2019	126 ± 6 ab	–	23 ± 7 b	77 ± 8 b	1 ± 1	14 ± 6 a	65 ± 2 b	20 ± 6 a
2020	120 ± 8 a	–	9 ± 12 a	91 ± 12 c	2 ± 1	23 ± 12 ab	46 ± 5 a	29 ± 9 a
2021	140 ± 15 bc	–	6 ± 3 a	94 ± 3 c	4 ± 3	32 ±12 b	41 ± 4 a	23 ± 18 a
GLMHL × YEAR	NS	–	NS	NS	–	NS	NS	NS

Table 7. *Cont.*

Specification	Mean Fruit Weight (g)	% of Fruit with Blush on Skin Surface Area			% of Fruit with Diameter (cm)			
		>75%	**25–75%**	**<25%**	**>8.5**	**7.5–8.5**	**6.5–7.5**	**<6.5**
Experiment No. 2								
GLMHL:								
Herbicide fallow	127 ± 3 b	–	14 ± 4 a	86 ± 4 c	3 ± 3	19 ± 4 b	51 ± 7 a	27 ± 8 a
Meadow grass 50	108 ± 11 a	4 ± 6	17 ± 6 ab	77 ± 3 bc	–	4 ± 5 a	39 ± 9 a	57 ± 13 b
Meadow grass 150	120 ± 5 ab	–	25 ± 6 bc	75 ± 6 abc	1 ± 1	9 ± 3 ab	51 ± 9 a	39 ± 8 ab
Perennial ryegrass 50	126 ± 12 b	–	26 ± 3 bc	73 ± 3 ab	1 ± 1	15 ± 8 b	50 ± 5 a	34 ± 13 a
Perennial ryegrass 150	119 ± 9 ab	1 ± 2	34 ± 6 c	64 ± 4 a	5 ± 5	11 ± 2 ab	43 ± 10 a	40 ± 13 ab
YEAR:								
2018	128 ± 6 b	–	50 ± 5 c	50 ± 5 a	–	10 ± 5 ab	50 ± 10 b	40 ± 13 a
2019	111 ± 7 a	–	25 ± 3 b	75 ± 3 b	–	6 ± 3 a	50 ± 5 b	44 ± 8 a
2020	119 ± 13 ab	5 ± 4	11 ± 5 a	84 ± 4 bc	6 ± 3	16 ± 6 b	35 ±7 a	43 ± 8 a
2021	123 ± 11 ab	–	7 ± 2 a	93 ± 2 c	2 ± 1	15 ± 5 b	51 ± 5 b	31 ± 9 a
GLMHL × YEAR	***	–	***	**	–	***	*	NS

GLMHL— living grass mulch species and seed sowing dose (kg·ha^{-1}) or herbicide fallow. NS—not significant. * Statistically significant differences at p value ≤ 0.05. ** Statistically significant differences at p value ≤ 0.01. *** Statistically significant differences at p value ≤ 0.001. Means marked with different letters in separate columns represent statistical differences among treatments (two-way ANOVA, Tukey test, $p \leq 0.05$).

3.6. Influence of Agrotechnical Methods versus Weather Conditions on Fruit Quality

Living mulch is one of the floor management options that eliminates the use of glyphosate in rows of fruit trees. It has a positive influence on the agricultural environment. On the other hand, living mulch competes with fruit trees, which was also visible in the present study (Tables 5 and 6). In these studies, there was also a contrasting milder effect of the tested fescues on the growth and yield of apple trees compared to the stronger effect of perennial ryegrass and meadow grass. However, it should be taken into account that at the time of sowing mulch seeds, the trees in experiment no. 2 were weaker compared to those grown in experiment no. 1 with both fescues. Access to available forms of potassium, phosphorus, and magnesium in the soil can be considered correct (Table 3).

The development of trees in experiment no. 2 was probably limited by the nitrogen availability, which also benefited the cover crops, as in the studies of TerAvest et al. [53]. Another limiting factor was probably water. Its availability is closely related to the biomass production of cover crops [43] and is also used by perennial weeds, the appearance of which in experiment no. 2 was more abundant than in experiment no. 1. Such conditions limiting the growth and development of trees in perennial ryegrass and meadow grass also determined the quality of the fruit, especially its blush color. The synthesis of anthocyanins, responsible for the red appearance of apples, is not favored by excessive tree vigor, especially excessive shoot growth [54]. As shown by Andersen et al. [26], in the presence of cover plants, the annual increment of shoots is significantly reduced. Hence, also in the present research in experiment no. 2, in which grass cover crops significantly weakened the growth of trees (Table 6), an increase in the share of apples was observed where the red blush color reached 25–75% of the fruit skin surface. Limiting the conditions of tree growth and development had a weaker impact on the average weight and size of apples. But such a situation occurred only with meadow grass cultivation with sowing of 50 kg of seeds per ha, when both the mean fruit weight and the share of fruit in the 7.5–8.5 cm apple class were significantly lower compared to the herbicide fallow control.

Fruit quality is determined by agronomic factors, such as orchard design and the training system or pruning of trees, and environmental factors, such as temperature and light distribution. It is also regulated by crop load and fruit set thinning [29]. In our research, the unification of agrotechnical methods in all treatments with living mulches and herbicide fallow excluded the influence on the weight, size, or blushing of the fruit of factors other than the presence of a cover crop. However, it seems that the relatively low level of yield, especially in the case of weaker-growing and low-yielding trees in experiment no. 2, also did not have a negative impact on fruit quality in the young orchard of 'Chopin' cv. (Tables S2 and S3). However, weather conditions were variable (Tables 1 and S1). In both experiments, the share of apples with red blush on the skin surface from 25 to 75% was significantly higher in 2018 compared to 2019 (Table 7). The share of red color apples in the first two years of fruiting differed significantly from those obtained in 2020 and 2021. This phenomen was related to low temperatures during fruit ripening, which is a factor that stimulates the red color of apples [33,35]. In our studies, the number of days with a minimum temperature ranging from 0 to 5.0 °C was positively correlated with an increase in the share of fruits with a red color covering 25–75% of the skin surface in each orchard floor management (Table 8).

Table 8. Linear correlation coefficient between selected thermal climatic conditions during fruit ripening or total annual precipitation in the years 2018–2021 and two fruit quality features of 'Chopin' cv. in relation to living grass mulch sods and herbicide fallow.

Specification	No. of Days with Low Temperature (°C)		No. of Days with High Temperature (°C)		No. of Days with Daily Temperature Amplitude (°C)		Total January–September Precipitation (mm)
	0.0–5.0	0.0–10.0	>20.0	>25.0	10.0–20.0	15.0–20.0	
Experiment No. 1							
% of fruit with blush on skin surface area 25–75%:							
Herbicide fallow	0.71	−0.71	NS	NS	NS	NS	−0.67
Blue fescue 50	0.65	−0.65	NS	NS	NS	NS	−0.62
Blue fescue 150	0.80	−0.73	NS	NS	0.57	NS	−0.67
Red fescue 50	0.78	−0.75	NS	NS	0.57	NS	−0.67
Red fescue 150	0.56	NS	NS	NS	0.59	NS	NS
% of fruit with diameter 7.5–8.5 cm:							
Herbicide fallow	NS	NS	NS	NS	NS	NS	NS
Blue fescue 50	NS	NS	NS	NS	NS	NS	NS
Blue fescue 150	NS	NS	0.56	NS	NS	NS	NS
Red fescue 50	NS	NS	NS	NS	NS	NS	NS
Red fescue 150	NS	0.52	NS	NS	NS	NS	NS
Experiment No. 2							
% of fruit with blush on skin surface area 25–75%:							
Herbicide fallow	0.50	−0.81	NS	NS	NS	NS	−0.77
Meadow grass 50	0.68	−0.63	NS	NS	NS	NS	−0.58
Meadow grass 150	0.64	NS	NS	NS	0.59	NS	NS
Perennial ryegrass 50	0.86	−0.79	NS	NS	0.58	NS	−0.73
Perennial ryegrass 150	0.93	−0.53	NS	0.64	0.80	0.59	NS
% of fruit with diameter 7.5–8.5 cm:							
Herbicide fallow	NS	NS	0.50	NS	NS	NS	NS
Meadow grass 50	NS	NS	NS	NS	NS	NS	NS
Meadow grass 150	−0.56	0.71	NS	NS	NS	NS	0.65
Perennial ryegrass 50	NS	NS	NS	NS	NS	NS	NS
Perennial ryegrass 150	NS	0.92	NS	NS	NS	NS	0.96

NS—not significant (linear correlation $p = 0.05$).

There were the most such days in 2018 (Table 1). In the following year, 2019, which also stimulated the red coloring of apples, there were fewer such days. However, in the last decade before harvest, the number of days with a daily temperature amplitude range from 10.0 to 20.0 °C was high, which was also significantly correlated with the increase in the share of red-skinned apples cultivated in living mulch. The influence of weather conditions on the weight and size of the fruit was small. However, it is worth noting that in experiment no. 2, with the increase in precipitation, the share of large fruits with a diameter of 7.5–8.5 cm increased significantly in two treatments with the sowing of meadow bluegrass and grass ryegrass at a dose of 150 kg of seeds per ha (Table 8). This proves that the improvement of water conditions mitigated the competitive impact of dense sod against fruit trees.

In our experience, the external quality of the fruit of new, scab-resistant 'green peel' 'Chopin' cv. was primarily influenced by weather conditions. Agricultural practice, similar to the experiment of Le Bourvellec et al. [6], was of secondary importance. Other comprehensive assessments of new 'Chopin' cv. trees have been carried out in recent years and they showed significant changes in the quality of the internal fruit as a result of changing weather conditions in subsequent growing seasons [52,55]. Additionally, attention was paid to the high acidity of apples, which seems to be an advantage of this cultivar compared to commonly produced 'red skin' apples in Poland, e.g., 'Idared' or 'Sampion' [55]. Such properties of the fruit also broaden the spectrum of its use compared to other sweeter 'green peel' apples like 'Golden Delicious' or 'Mutsu' [52]. As we have shown, in the example of a young orchard with 'Chopin' cv., the first effect of the presence of living mulch on the group of 'green apple' cultivars was the appearance of a certain amount of fruit with slightly red-pink colored skin. In favorable growing seasons, the share of such fruits will increase significantly. The producer's care for the agricultural environment and an increase in consumer awareness should favor the acceptance of the presence of red blushing on 'green peel' apples (Scheme S1). This is also justified by the fact that as the area of red skin color increases, the share of anthocyanins in the apple peel also increases [54], which are phenolic compounds that are important for human health [56,57].

4. Conclusions

Several years of research on the new scab-resistant apple tree cultivar 'Chopin' shows that the yield and growth of the trees were influenced by cover crop presence as well as grafting trees on one of the strongest semi-dwarf rootstocks—MM.106. The quality of fruit was determined by environmental rather than agrotechnical factors. Nevertheless, an unexpected effect of the presence of living mulch was its significant influence on fruit appearance, showing a red-pink blush on the 'green peel' fruit of 'Chopin' cv. Low temperatures and moderate rainfall during the apple ripening period enhanced the red coloration of the fruit skin. Modifications of fruit quality by the presence of a cover crop and weather conditions were stronger in the case of weaker trees cultivated with meadow grass and perennial ryegrass compared to more vigorous trees grown in fescue grasses. This was influenced by the early germination and faster development of these living grass mulches and the presence of weeds, mainly *Trifolium repens* L., in their sod. Increasing the sowing rate of grass seeds had no direct impact on the quality of the fruit. The presence of living mulch and weather conditions had little effect on fruit mean weight and fruit size.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/agriculture14040610/s1. Figure S1: Daily minimum and maximum temperatures at the Wrocław-Strachowice Station (51°12′ N, 16°87′ E) in September in the years 2018–2021; Figure S2: Blooming of 'Chopin' trees with living blue fescue or red fescue mulch sods or herbicide fallow—experiment no. 1 (scale 1–6); Figure S3: Blooming of 'Chopin' trees with living meadow grass or perennial ryegrass mulch sods or herbicide fallow—experiment no. 2 (scale 1–6); Table S1: Mean temperatures and total precipitation at the Wrocław-Strachowice Station (51°12′ N, 16°87′ E) in the years 2016–2021; Table S2: Fruit number and yield of 'Chopin' cv. with living blue fescue or red fescue mulch sods or herbicide fallow—experiment no. 1, in the individual years since 2017 up to 2021 (mean ± SD, n = 4); Table S3: Fruit number and yield of 'Chopin' cv. with living meadow grass or perennial ryegrass mulch sod or herbicide fallow—experiment no. 2, in the individual years since 2017 up to 2021 (mean ± SD, n = 4); Scheme S1: Red-pink blushing on the fruit skin surface of the green–peel 'Chopin' cv. in the autumn of 2018.

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References

1. Sivaperumal, P.; Thasale, R.; Kumar, D.; Mehta, T.G.; Limbachiya, R. Human Health Risk Assessment of Pesticide Residues in Vegetable and Fruit Samples in Gujarat State, India. *Heliyon* **2022**, *8*, e10876. [CrossRef]
2. Jankowska, M.; Hrynko, I.; Łozowicka, B. Human Health Risk Assessment of Pesticide Residues in Fruit, Vegetable and Cereal Samples from Poland–a 5-Year Survey. *J. Plant Prot. Res.* **2023**, *62*, 385–392. [CrossRef]
3. Qi, Y.; Li, J.; Guan, X.; Yan, B.; Fu, G.; He, J.; Du, L.; Zhao, C.; Zhang, D. Effects of Herbicides on Non-Target Plant Species Diversity and the Community Composition of Fallow Fields in Northern China. *Sci. Rep.* **2020**, *10*, 9967. [CrossRef] [PubMed]
4. Fogliatto, S.; Ferrero, A.; Vidotto, F. Current and Future Scenarios of Glyphosate Use in Europe: Are There Alternatives? *Adv. Agron.* **2020**, *163*, 219–278. [CrossRef]
5. Paušič, A.; Tojnko, S.; Lešnik, M. Permanent, Undisturbed, in-Row Living Mulch: A Realistic Option to Replace Glyphosate-Dominated Chemical Weed Control in Intensive Pear Orchards. *Agric. Ecosyst. Environ.* **2021**, *318*, 107502. [CrossRef]
6. Le Bourvellec, C.; Bureau, S.; Renard, C.M.G.C.; Plenet, D.; Gautier, H.; Touloumet, L.; Girard, T.; Simon, S. Cultivar and Year Rather than Agricultural Practices Affect Primary and Secondary Metabolites in Apple Fruit. *PLoS ONE* **2015**, *10*, e0141916. [CrossRef]
7. Baluszynska, U.B.; Licznar-Malanczuk, M.; Medic, A.; Veberic, R.; Grohar, M.C. Influence of Living Mulch and Nitrogen Dose on Yield and Fruit Quality Parameters of *Malus domestica* Borkh. cv. 'Sampion'. *Agriculture* **2023**, *13*, 921. [CrossRef]
8. Bałuszyńska, U.B.; Rowińska, M.; Licznar-Małańczuk, M. Grass Species as Living Mulches–Comparison of Weed Populations and Their Biodiversity in Apple Tree Rows and Tractor Alleys. *Acta Agrobot.* **2022**, *75*, 758. [CrossRef]
9. Demir, Z.; Tursun, N.; Dogan, I. Effects of Different Cover Crops on Soil Quality Parameters and Yield in an Apricot Orchard. *Int. J. Agric. Biol.* **2019**, *21*, 25–33.
10. Mia, M.J.; Massetani, F.; Murri, G.; Neri, D. Sustainable Alternatives to Chemicals for Weed Control in the Orchard–A Review. *Hortic. Sci.* **2020**, *47*, 1–12. [CrossRef]
11. Golian, J.; Anyszka, Z.; Kwiatkowska, J. Multifunctional Living Mulches for Weeds Control in Organic Apple Orchards. *Acta Sci. Pol. Hortorum Cultus* **2023**, *22*, 73–84. [CrossRef]
12. Hammermeister, A.M. Organic Weed Management in Perennial Fruits. *Sci. Hortic.* **2016**, *208*, 28–42. [CrossRef]
13. Hussain, S.; Sharma, M.K.; War, A.R.; Hussain, B. Weed Management in Apple Cv. Royal Delicious by Using Different Orchard Floor Management Practices. *Int. J. Fruit. Sci.* **2020**, *20*, 891–921. [CrossRef]
14. Haring, S.; Gaudin, A.C.M.; Hanson, B.D. Functionally Diverse Cover Crops Support Ecological Weed Management in Orchard Cropping Systems. *Renew. Agric. Food Syst.* **2024**, *38*, e54. [CrossRef]
15. Qian, X.; Gu, J.; Pan, H.J.; Zhang, K.Y.; Sun, W.; Wang, X.J.; Gao, H. Effects of Living Mulches on the Soil Nutrient Contents, Enzyme Activities, and Bacterial Community Diversities of Apple Orchard Soils. *Eur. J. Soil Biol.* **2015**, *70*, 23–30. [CrossRef]
16. Żelazny, W.R.; Licznar-Małańczuk, M. Soil Quality and Tree Status in a Twelve-Year-Old Apple Orchard under Three Mulch-Based Floor Management Systems. *Soil Tillage Res.* **2018**, *180*, 250–258. [CrossRef]
17. Brewer, M.; Kanissery, R.G.; Strauss, S.L.; Kadyampakeni, D.M. Impact of Cover Cropping on Temporal Nutrient Distribution and Availability in the Soil. *Horticulturae* **2023**, *9*, 1160. [CrossRef]
18. Chen, G.; Liu, S.; Xiang, Y.; Tang, X.; Liu, H.; Yao, B.; Luo, X. Impact of Living Mulch on Soil C:N:P Stoichiometry in Orchards across China: A Meta-Analysis Examining Climatic, Edaphic, and Biotic Dependency. *Pedosphere* **2020**, *30*, 181–189. [CrossRef]
19. Yang, J.; Duan, Y.; Zhang, R.; Liu, C.; Wang, Y.; Li, M.; Ding, Y.; Awasthi, M.K.; Li, H. Connecting Soil Dissolved Organic Matter to Soil Bacterial Community Structure in a Long-Term Grass-Mulching Apple Orchard. *Ind. Crops Prod.* **2020**, *149*, 112344. [CrossRef]
20. Furmanczyk, E.M.; Malusà, E.; Kozacki, D.; Tartanus, M. Insights into the Belowground Biodiversity and Soil Nutrient Status of an Organic Apple Orchard as Affected by Living Mulches. *Agriculture* **2024**, *14*, 293. [CrossRef]
21. Capri, C.; Gatti, M.; Fiorini, A.; Ardenti, F.; Tabaglio, V.; Poni, S. A Comparative Study of Fifteen Cover Crop Species for Orchard Soil Management: Water Uptake, Root Density Traits and Soil Aggregate Stability. *Sci. Rep.* **2023**, *13*, 721. [CrossRef] [PubMed]
22. Licznar-Małańczuk, M.; Kwiecińska, I. Application of Living Mulch in Rows of the Apple Trees on Several Rootstock-Long-Term Evaluation. *Acta Sci. Pol. Hortorum Cultus* **2023**, *22*, 79–90. [CrossRef]
23. Kühn, B.F.; Lindhard Pedersen, H. Cover Crop and Mulching Effects on Yield and Fruit Quality in Unsprayed Organic Apple. *Eur. J. Hortic. Sci.* **2009**, *74*, 247–253.
24. Atucha, A.; Merwin, I.A.; Brown, M.G. Long-Term Effects of Four Groundcover Management Systems in an Apple Orchard. *HortScience* **2011**, *46*, 1176–1183. [CrossRef]
25. Tworkoski, T.J.; Michael Glenn, D. Weed Suppression by Grasses for Orchard Floor Management. *Weed Technol.* **2012**, *26*, 559–565. [CrossRef]

26. Andersen, L.; Kühn, B.F.; Bertelsen, M.; Bruus, M.; Larsen, S.E.; Strandberg, M. Alternatives to Herbicides in an Apple Orchard, Effects on Yield, Earthworms and Plant Diversity. *Agric. Ecosyst. Environ.* **2013**, *172*, 1–5. [CrossRef]
27. Tahir, I.I.; Svensson, S.-E.; Hansson, D. Floor Management Systems in an Organic Apple Orchard Affect Fruit Quality and Storage Life. *HortScience* **2015**, *50*, 434–441. [CrossRef]
28. Sosna, I.; Fudali, E. Usefulness of Living Mulch in Rows in a Dwarf Pear, *Pyrus communis* L., Orchard. *Agriculture* **2023**, *13*, 2145. [CrossRef]
29. Musacchi, S.; Serra, S. Apple Fruit Quality: Overview on Pre-Harvest Factors. *Sci. Hortic.* **2017**, *234*, 409–430. [CrossRef]
30. Seppä, L.; Railio, J.; Vehkalahti, K.; Tahvonen, R.; Tuorila, H. Hedonic Responses and Individual Definitions of an Ideal Apple as Predictors of Choice. *J. Sens. Stud.* **2013**, *28*, 346–357. [CrossRef]
31. Drkenda, P.; Ćulah, A.; Spaho, N.; Akagić, A.; Hudina, M. How Do Consumers Perceive Sensory Attributes of Apple? *Foods* **2021**, *10*, 2667. [CrossRef] [PubMed]
32. Atay, E.; Gargin, S.; Esitken, A.; Guzel, N.P.; Atay, A.N.; Altindal, M.; Senyurt, H.; Emre, M. The Effect of Weed Competition on Apple Fruit Quality. *Not. Bot. Horti Agrobot. Cluj-Napoca* **2017**, *45*, 120–125. [CrossRef]
33. Saure, M.C. External Control of Anthocyanin Formation in Apple. *Sci. Hortic.* **1990**, *42*, 181–218. [CrossRef]
34. Singh, A.; Kishore, K.; Kumar, P.; Khapte, P.S.; Mishra, D.S.; Singh, D.; Kothyari, H.S. Phenological Growth and Development Stages of Common Fig (*Ficus Carica* L.) under Arid Climate of India. *Folia Hortic.* **2023**, *35*, 395–402. [CrossRef]
35. Honda, C.; Moriya, S. Anthocyanin Biosynthesis in Apple Fruit. *Hort. J.* **2018**, *87*, 305–314. [CrossRef]
36. Warrington, I.J.; Fulton, T.A.; Halligan, E.A.; De Silva, H.N. Apple Fruit Growth and Maturity Are Affected by Early Season Temperatures. *J. Am. Soc. Hortic. Sci.* **1999**, *124*, 468–477. [CrossRef]
37. Lipecki, J.; Janisz, A. Rozmieszczenie Przestrzenne Oraz Zmiany w Występowaniu Niektórych Gatunków Chwastów w Sadzie Jabłoniowym Gospodarstwa Doświadczalnego Felin Koło Lublina [Spatial Distribution and Changes in Occurrence of Some Weeds Species in the Orchard in AES Felin near Lublin]. *Acta Agrobot.* **2000**, *53*, 85–104.
38. POWO Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet. Available online: http://www.Plantsoftheworldonline.Org/ (accessed on 18 March 2024).
39. Ziadi, N.; Sen Tran, T. Mehlich-3 Extractable Elements. In *Soil Sampling and Methods of Analysis*; Carter, M.R., Gregorich, E.G., Eds.; CRC Press: Boca Raton, FL, USA, 2008; pp. 81–87.
40. Korzeniowska, J.; Stanisławska-Glubiak, E.; Lipiński, W. Development of the Limit Values of Micronutrient Deficiency in Soil Determined Using Mehlich 3 Extractant for Polish Soil Conditions. Part I. Wheat. *Soil Sci. Annu.* **2019**, *70*, 314–323. [CrossRef]
41. Buurman, P.; van Lagen, B.; Velthorst, E.J. *Manual for Soil and Water Analysis*; Bakhuys Publishers Leiden: Amsterdam, The Netherlands, 1996.
42. Sadowski, A.; Nurzyński, J.; Pacholak, E.; Smolarz, K. *Określanie Potrzeb Nawożenia Roślin Sadowniczych II. Zasady, Liczby Graniczne i Dawki Nawożenia. [Determining the Fertilization Needs of Fruit Plants II. Rules, Limit Numbers and Fertilization Doses]*; Warsaw University of Life Sciences: Warszawa, Poland, 1990.
43. Nielsen, D.C.; Lyon, D.J.; Hergert, G.W.; Higgins, R.K.; Holman, J.D. Cover Crop Biomass Production and Water Use in the Central Great Plains. *Agron. J.* **2015**, *107*, 2047–2058. [CrossRef]
44. Haring, S.C.; Hanson, B.D. Agronomic Cover Crop Management Supports Weed Suppression and Competition in California Orchards. *Weed Sci.* **2022**, *70*, 595–602. [CrossRef]
45. Bertin, C.; Senesac, A.F.; Rossi, F.S.; Ditommaso, A.; Weston, L.A. Evaluation of Selected Fine-Leaf Fescue Cultivars for Their Turfgrass Quality and Weed Suppressive Ability in Field Settings. *Horttechnology* **2009**, *19*, 660–668. [CrossRef]
46. Gawryluk, A. The Influence of Sowing Date on Initial Growth and Development of Selected Lawn Varieties of *Festuca Arundinacea*, *Festuca Rubra*, *Festuca Ovina*, *Lolium Perenne* and *Poa Pratensis* on a Roadside Bank. *Agron. Sci.* **2019**, *74*, 57–66. [CrossRef]
47. Licznar-Małańczuk, M. Occurrence of Weeds in an Orchard Due to Cultivation of Long-Term Perennial Living Mulches. *Acta Agrobot.* **2020**, *73*, 1–11. [CrossRef]
48. Mézière, D.; Petit, S.; Granger, S.; Biju-Duval, L.; Colbach, N. Developing a Set of Simulation-Based Indicators to Assess Harmfulness and Contribution to Biodiversity of Weed Communities in Cropping Systems. *Ecol. Indic.* **2014**, *48*, 157–170. [CrossRef]
49. Ramos, M.E.; Robles, A.B.; Sánchez-Navarro, A.; González-Rebollar, J.L. Soil Responses to Different Management Practices in Rainfed Orchards in Semiarid Environments. *Soil Tillage Res.* **2011**, *112*, 85–91. [CrossRef]
50. Kosina, J. Effect of Dwarfing and Semi Dwarfing Apple Rootstocks on Growth and Productivity of Selected Apple Cultivars. *Hort. Sci.* **2010**, *37*, 121–126. [CrossRef]
51. Zenginbal, H.; Öztürk, T.; Faizi, Z.A. Bacterial Strains Effect on the Nursery Plants Growth of 'Granny' Apple Grafted on M-9, MM-106, and MM-111 Rootstocks. *Biocatal. Agric. Biotechnol.* **2023**, *50*, 102747. [CrossRef]
52. Sawicka, M.; Latocha, P.; Łata, B. Peel to Flesh Bioactive Compounds Ratio Affect Apple Antioxidant Potential and Cultivar Functional Properties. *Agriculture* **2023**, *13*, 478. [CrossRef]
53. TerAvest, D.; Smith, J.L.; Carpenter-Boggs, L.; Hoagland, L.; Granatstein, D.; Reganold, J.P. Influence of Orchard Floor Management and Compost Application Timing on Nitrogen Partitioning in Apple Trees. *HortScience* **2010**, *45*, 637–642. [CrossRef]
54. Treutter, D. Biosynthesis of Phenolic Compounds and Its Regulation in Apple. *Plant Growth Regul.* **2001**, *34*, 71–89. [CrossRef]
55. Kistechok, A.; Wrona, D.; Krupa, T. Quality and Nutritional Value of 'Chopin' and Clone 'JB' in Relation to Popular Apples Growing in Poland. *Agriculture* **2022**, *12*, 1876. [CrossRef]

56. Nezbedova, L.; McGhie, T.; Christensen, M.; Heyes, J.; Nasef, N.A.; Mehta, S. Onco-Preventive and Chemo-Protective Effects of Apple Bioactive Compounds. *Nutrients* **2021**, *13*, 4025. [CrossRef] [PubMed]
57. Hyson, D.A. A Comprehensive Review of Apples and Apple Components and Their Relationship to Human Health. *Adv. Nutr.* **2011**, *2*, 408–420. [CrossRef]